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EFFECT OF DEHYDRATION VARIABLES ON THE QUALITY OF  
FREEZE-DRIED COOKED SLICED BEEF

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AS OF 1962

Interim Report  
June 1962



QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES  
QUARTERMASTER RESEARCH AND ENGINEERING COMMAND, U.S. ARMY  
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QMFCIAF REPORT NO. 14-62

PROJECT: 7-84-06-032  
Development

Effect of Dehydration Variables on the Quality of  
Freeze-Dried Cooked Sliced Beef

Interim Report

by

J. M. Tuomy, R. J. Lechnir, Terrance Miller

Meat Products Branch

Food Division

June 1962

Quartermaster Food and Container Institute for the Armed Forces

EFFECT OF DEHYDRATION VARIABLES ON THE QUALITY OF  
FREEZE-DRIED COOKED SLICED BEEF

SUMMARY

This interim report gives the results of a factorial experiment on the effects of dehydration variables on the quality of freeze-dried cooked sliced beef. The variables investigated were Platen Temperature, Dehydrator Pressure, Pre-freezing vs. Evaporative Freezing, and Over-drying.

Platen temperature by itself and overdrying had no significant effects on the tenderness, cuttability, or juiciness of the product. Evaporative freezing and higher dehydrator pressures were found to adversely affect the product.

The work reported is part of a larger study which includes the effect of both pre-dehydration and dehydration variables on tenderness and other acceptance criteria, the study of other methods for attaining optimum tenderness such as enzyme treatments, the investigation of objective methods for determining tenderness in the final product, and the study of other meats such as pork.

## EFFECT OF DEHYDRATION VARIABLES ON THE QUALITY OF FREEZE-DRIED COOKED SLICED BEEF

A previous report (1) has shown the effects of Meat Grade, State (fresh or frozen), Methods of Cooking, Degree of Cook, and Speed of Freezing (for dehydration) on the tenderness, cuttability, and juiciness of cooked, sliced, freeze-dehydrated beef. This report is concerned with the effect of dehydration variables on the same properties of cooked, sliced, freeze-dehydrated beef. Both these investigations are part of a larger study which will cover other methods of obtaining tenderness such as by enzymes, other meats such as cooked and raw pork and poultry, and the development of objective measurements for quality aspects such as tenderness. The variables under consideration in this phase are: Platen temperature, Dehydrator pressure, Pre-freezing vs. Evaporative freezing, and Overdrying.

The use of freeze-drying for foods has been an offshoot of its use in the pharmaceutical industry. Efforts with food have been directed mainly toward the development of prototype items using a process known to produce satisfactory pharmaceuticals. The trend in the pharmaceutical industry is toward even more gentle processes, whereas the trend with foods is toward more severe processes in order to reduce costs. It is the purpose of this report to assess effects of changing process variables in the organoleptic properties, particularly tenderness, of cooked, sliced, freeze-dehydrated beef.

The main process variables of concern in freeze-drying are the chamber pressure and the rate of heat input. The chamber pressure must of necessity be maintained below the triple point of water (4.6 mm) to prevent thawing during the process. Current Purchase Descriptions for the procurement of dehydrated meat specify a maximum chamber pressure of 1.5 mm, a pressure easily obtainable with modern commercial equipment. However, relaxing of this requirement could be reflected in reduced costs.

The rate of heat input is extremely important to process economics since it is the controlling factor in process time for any given product. With present commercial equipment, the rate of vapor removal is sufficiently high so that the rates of heat input either now used or contemplated will not overtake it and thus cause a rise in product ice temperature. However, the temperature of the dried portions of the product rises during the process and, although the dried product is much less sensitive to temperature than the raw product, it will be perceptibly damaged in time by high temperatures.

Two other factors which could affect product quality in freeze-drying are evaporative freezing of the product in the dehydrator chamber rather than pre-freezing and the amount of overdrying necessary to assure complete drying. Evaporative freezing has been suggested as a means of reducing equipment and labor costs. Overdrying is necessary because of the lack of adequate means for the accurate determination of the process endpoint.

Since the development of the freeze-dehydration process for food is still in the early stages, literature on process variables is rather meager and inconclusive. On the other hand, work has been reported in the biological and pharmaceutical fields which gives some insight into their effects, although the results are not directly translatable to foods since biological viability is not necessarily important with food. Greaves (2) states that on theoretical grounds drying should take place below the lowest eutectic temperature of the product. In practice this is seldom possible and provided the quantity of the eutectic solution present is small compared with the quantity of protein, the amount of denaturation occurring in the product is so slight as to be undetectable by present methods. Rey (3) states that one of the most important factors in freeze-drying is the regulation of the product temperature during the course of drying. Further, he blamed limited melting of eutectic mixtures or softening of the hard structures of frozen product for denaturation that occurs in unsuccessful freeze-drying. Meryman (4) also blamed tissue injury on the formation of eutectic solutions. It is doubtful that the formation of eutectics has such adverse effects on foodstuffs but undoubtedly it has some effect. Since the product temperature during drying depends upon the chamber pressure, it follows that the qualities of freeze-dried foods may be affected by chamber pressure. Rolfe (5) has compared the qualities of vacuum-dried and freeze-dried meats. He did not attempt to delineate the effects of variables within the freeze-drying process, but did point out that the adverse effects of vacuum-drying (shrinkage and formation of an impermeable shell on the surface with resulting poor rehydrated texture)

are present to some extent when product to be freeze-dried is evaporatively frozen in the drying chamber. Rolfe stated that evaporative freezing could not be used successfully with raw meat, but could be used with cooked meat. However, he did not attempt to make any objective determinations of the differences between evaporatively frozen and pre-frozen meat.

In freeze-drying foods, the individual pieces do not dry at a uniform rate. Kan (6) demonstrated this with uniform sized pieces of raw beef and the same phenomena has been demonstrated with various products at this Institute. Because of this fact and because there is no adequate method presently available for determining whether every piece is dry without opening the dryer, it has been customary to deliberately extend the freeze-drying process as much as an hour longer than such devices as thermocouples in the product would indicate as being necessary. Although this is an accepted practice in the freeze-drying industry, no evaluation has been made as to its effect on product quality such as tenderness.

#### Experimental Methods

Since the work covered in this report is a continuation of the work reported previously (1) and is concerned with the same product, one set of pre-dehydration variables was selected from the previous work and experimental procedures handled identically with this work.

Fresh canned and cutter inside rounds were used with no attempt to control quality other than grade designation and soundness. The rounds were trimmed of excess fat and cut into several pieces. Each sample consisted of two or more pieces which were selected as randomly as possible.

Products which were not to be cooked until the following day were held in a 32°F. cooler.

Cooking was accomplished in steam using four-inch diameter, round, spring-loaded, stainless steel molds. Steam pressure was 10 pounds per square inch and the cooking time was two hours. After cooking, the springs were reset and the product placed in a 40°F. cooler overnight. The following day the product was sliced one-fourth-inch thick and slices containing gristle, excess fat, or other defects and slices cut parallel with the fibers eliminated. The slices to be pre-frozen were frozen on dehydrator trays in a blast freezer with a freezing plateau of about eight minutes. Product to be evaporatively frozen was held on dehydrator trays in a 32°F. cooler until placed in the dehydrator.

The dehydration process was monitored by the use of thermocouples placed in the meat. Process endpoint was determined as the time the internal temperature of the product leveled off plus one-half hour. Product to be overdried was held in the dehydrator an additional two hours.

Evaluation of the product was accomplished as in the previous study by a 24 subject panel of technologists rating the product for tenderness, juiciness, and cuttability on a nine-point rating scale. Flavor was rated separately by an informal technological panel on a nine-point rating scale.

## Results and Discussion

Table 1 shows the means for panel evaluation of tenderness. Table 2 shows the effects of variables on tenderness, cuttability, and juiciness along with the probabilities (P) for significance of difference. Small probabilities, such as  $P=0.05$  or "significant at the 5% level", indicate that the hypothesis of true difference in a comparison is likely to be true.

Platen temperature. In general, the platen temperature by itself had no significant effect on the tenderness, cuttability, or juiciness of the product. It has been suggested (7) that the heating cycle for freeze-drying be programmed so that product temperature never exceeds a given value. This would involve starting out at a high platen temperature such as  $300^{\circ}\text{F}$ . and gradually reducing it so that the product temperature never exceeds a value such as  $140^{\circ}\text{F}$ . For the purpose of this study, programming was not considered due to the complexities it would introduce into the experimental design. However, maintaining the platen temperatures at the experimental values during the entire process subjected the product to more severe conditions than ordinarily would be considered for a programmed cycle except for the lowest value of  $150^{\circ}\text{F}$ . Since this study shows no significant effect of platen temperature on tenderness, cuttability, and juiciness, it would appear that programming would not affect these attributes. The effect on other attributes should be assessed.

Chamber Pressure. There was a significant improvement of tenderness and cuttability with the lower pressure. No effect on juiciness was shown. This would indicate that lower pressures should be used in freeze-dehydrating cooked beef. Since only two pressures (0.75 and 2.0 mm)

were investigated it would appear that further work would be desirable especially on still lower pressures. However, the present QMFCIAF equipment is designed with a dead end of 0.5 mm and a low operating pressure of 0.75 mm so that studies of lower pressure will have to wait until suitable equipment becomes available to the Institute.

Freezing. It is evident from this study that evaporative freezing in the dehydration chamber has an adverse effect on tenderness, cuttability, and juiciness. This is in line with previous work at this Institute which had indicated that evaporative freezing could be used, but that usually the product was not quite as good as when it was pre-frozen.

Overdrying. There was no effect demonstrated on tenderness, cuttability, or juiciness when the product was overdried. This would indicate that overdrying customarily done to assure that all of the product is dry is not critical to the product attributes investigated.

Two factor interactions. The statistical analysis of the data indicated that there were several two-factor interactions of significance as shown in Table 2. Platen temperature which by itself showed no effect, when considered in combination with pressure, freezing, and overdrying resulted in significant effects. In general, the interactions favored the direction indicated by the single variables.

Flavor. Flavor was evaluated by an informal technological panel and the results shown in Table 3 do not lend themselves to statistical analysis. However, the results do suggest that the variables studied had little effect on flavor.

### Conclusions

It is evident that from this investigation that the tenderness, cuttability, and juiciness of cooked sliced beef cannot be improved substantially by alterations in the process within the capabilities of present commercial equipment. They can be changed adversely by operating outside of what are now considered good operating limits such as higher operating pressures. Since the lower pressure, which is in the range currently used, did give better results, still lower pressures should be investigated when equipment becomes available.

Evaporative freezing did not give as good results as pre-freezing. However, it has not been proven that the resulting product is not satisfactory for the intended use and a more detailed investigation should be made including engineering studies as to projected monetary savings from such a procedure.

The use of high platen temperatures and overdrying did not seem to damage the product and thus the more severe processes are feasible with the accompanying decrease in process time. It should be noted that some studies with other products such as chicken and fish show that they "scorch" at higher temperatures. Separate studies will be made on these products.

A corollary on the adverse effect of evaporative freezing is that thawing in the dehydrator followed by freezing will adversely affect the product since this freezing is evaporative.

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Table 1  
Tenderness Means

Pressure	0.75 mm				2.0 mm				Mean
	Pre-frozen		Evaporative		Pre-frozen		Evaporative		
	Normal	Over	Normal	Over	Normal	Over	Normal	Over	
Freezing									
Drying									
Plate Temp.									
150°	5.00	5.00	5.83	5.92	5.75	6.08	3.83	5.50	5.36
175°	6.42	4.92	5.66	4.92	5.92	5.83	5.75	5.58	5.63
200°	6.25	6.58	5.58	5.33	5.16	5.50	5.17	3.50	5.38
	5.89	5.50	5.69	5.39	5.61	5.80	4.92	4.86	

Table 2  
Effect of Variable

Variable	TENDERNESS		CUTTABILITY		JUICINESS	
	Effect	P	Effect	P	Effect	P
Platen Temperature	No effect	--	No effect	--	No effect	--
Dehy. Pressure	0.75 superior to 2.0 mm	.05	0.75 superior to 2.0 mm	.001	No effect	--
Freezing	Pre-frozen superior to evap.	.01	Pre-frozen superior to evap.	.01	Pre-frozen superior to evap.	.05
Dehydration	No effect		No effect		No effect	
Platen Temp X Pressure	Increased with temp at 0.75 mm, decreased at 2.0 mm	.01	Increased with high temp. 0.75 mm, decreased at 2.0 mm	.01	Best at 200° and 0.75 mm, 175° and 2.0 mm	.05
Platen Temp X Dehydration	Decreased at 150° normal drying. Increased from 150° to 175° and 200°F. for normal dehydration	.01	Increased with 150° over dehy. Increased from 150° to 175° and 200°F. for normal dehydration	.001	200°F. over dried was most juicy	.05
Platen Temp X Freezing	No effect		No effect		No effect	
Pressure X Freezing	No effect		0.75 mm pre-frozen had highest score	.05	No effect	
Pressure X Dehydration	Increased for 0.75 mm and normal dehy.	.05	No effect		No effect	
Freezing X Dehydration	No effect		No effect		No effect	

Table 3  
Flavor Means  
(Informal Technological Panel)

Pressure	0.75				2.0mm				
	Pre-frozen		Evaporative		Pre-frozen		Evaporative		
	Normal	Over	Normal	Over	Normal	Over	Normal	Over	
Freezing									Mean
Drying									
Plate Temp.									
150°	6.8	5.6	6.5	5.3	6.1	5.4	5.8	5.7	5.9
175°	5.0	5.9	4.6	5.9	6.0	5.8	5.4	5.9	5.6
200°	6.0	5.8	6.1	5.2	5.8	4.9	6.0	4.7	5.6
	5.9	5.8	5.7	5.5	6.0	5.4	5.7	5.4	

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